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Pavement Distress Analysis on Pakuhaji Road Section, Tangerang Regency Using the Indeks Kondisi Perkerasan (IKP) Method

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Abstract-- *Deteriorated pavement conditions can reduce road serviceability and pose safety risks to road users. Therefore, a systematic pavement condition evaluation is required to identify pavement distresses and determine appropriate maintenance strategies. This study aims to identify pavement distress types, evaluate pavement conditions, and propose maintenance recommendations for the Pakuhaji Road section in Tangerang Regency from STA 0+000 to STA 3+000 using the Pavement Condition Index method, locally referred to as the Indeks Kondisi Perkerasan (IKP).*

The research employed a visual field survey by dividing the ±1.5 km road section into 30 observation segments in each traffic direction. The collected data included distress types, severity levels, and distress dimensions, which were subsequently analyzed to determine the IKP value for each segment and classify the pavement condition. The results indicate that the dominant pavement distresses on the Pakuhaji Road include alligator cracking, potholes, raveling, and localized depressions along the pavement edges. The IKP values range from 38 to 68, indicating pavement conditions varying from failed to moderate. Pavement conditions in the Mauk direction are generally classified as severe to failed, while the Sepatan direction is predominantly classified as moderate to severe. Based on the evaluation results, routine and periodic maintenance is recommended for segments with good to moderate conditions, while structural improvement or reconstruction is required for segments with severe to failed conditions.

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1. INTRODUCTION

Road infrastructure plays a vital role in supporting economic, social, and cultural activities by facilitating the mobility of people, goods, and services [1]. The quality of road pavement directly affects user safety and comfort, making it essential to maintain adequate serviceability levels [2]. However, increasing vehicle volumes annually subject road pavements to higher traffic loads, accelerating wear and reducing design life [3]. Pavement distress manifests in various forms including cracking, raveling, and potholes, all of which indicate declining service quality [4]. Severely damaged roads not only disrupt travel but also increase accident risks and vehicle operating costs due to higher fuel consumption and component damage [5]. Research indicates that heavy vehicle dominance significantly accelerates pavement deterioration, particularly in developing countries where roads often fail before reaching their design life [6].

Similar problems occur on the Paku Haji Road section in Tangerang Regency, which serves as a vital inter-regional connector experiencing frequent pavement distress despite its importance. This road accommodates various vehicle types including freight transport, subjecting the pavement to high traffic loads that accelerate deterioration. Such conditions impede community mobility, disrupt goods distribution, and reduce user comfort and safety. Without timely intervention, road damage potentially creates broader economic and social impacts, from increased transportation costs to decreased community productivity.

Road maintenance cannot be conducted arbitrarily but must begin with objective pavement condition evaluation. Such evaluation is essential to identify distress types, severity levels, and distribution patterns, ensuring maintenance actions align with actual field conditions. In Indonesia, the standard method for pavement condition evaluation is the Indeks Kondisi Perkerasan (IKP) method, officially established through the Ministry of Public Works and Housing Circular Letter No. 19/SE/M/2016 concerning the Pavement Condition Index Guideline Pd 01-2016-B [7]. This guideline provides a quantitative assessment of pavement conditions with values ranging from 0 to 100, where higher values indicate better conditions. These values are classified into categories including excellent, very good, good, fair, poor, very poor, and failed.

The IKP method offers several advantages over other assessment methods. As a numerical indicator, IKP reflects the pavement surface condition at the time of survey based on observable distresses, indicating both structural integrity and functional condition (roughness and skid resistance) [7]. Although IKP cannot directly measure structural capacity, skid resistance, or roughness, it provides an objective and rational foundation for determining required maintenance and repair programs as well as treatment priorities [7].

Although research on road conditions has been conducted in various locations using various methods, studies focusing on the Pakuhaji Road section in Tangerang Regency using the official Indonesian IKP standard remain limited. This road section exhibits concerning conditions that directly impact community mobility. Therefore, pavement distress analysis on the Pakuhaji Road section using the IKP method based on Pd 01-2016-B is essential. This research aims to provide comprehensive understanding of actual pavement conditions and serve as a foundation for local government in determining maintenance priorities and strategies.

2. METHODOLOGY

2.1 Research Location

This research was conducted on the Pakuhaji Road section in Tangerang Regency, observing a 1.5 km segment. The research started from STA 0+000 at Apotek Sembilan Bintang Pakuhaji to STA 3+000 before the Pakuhaji District Office. Location characteristics are as follows:

- Road type: 2/2 UD
- Road function: Primary Collector Road
- Width: 3.5 meters per direction
- Total inspected segment length: 1500 m
- Pavement type: Flexible pavement

2.2 Sample Unit Determination

Based on the IKP guideline Pd 01-2016-B [7], pavement sections were divided into sample units with each unit having an area of (225 ± 90) m², meaning each unit must have an area ranging from 135 m² to 315 m². This research used 175 m² per unit (225 – 50 = 175), resulting in dimensions of 50 m length and 3.5 m width. For the 1500-meter road section, 30 sample units were obtained.
The minimum number of sample units requiring inspection to achieve 95% confidence level was calculated using Equation (1) from the IKP guideline [7]:

$$n = \frac{N \times d^2}{\frac{e^2}{4}(N-1)+d^2} \tag{1}$$

Where:

n = minimum number of sample units
N = total number of sample units in the section (30)
e = allowable error in estimating section IKP (assumed ±5% or 0.05)
d = standard deviation of IKP between sample units (assumed 10 for asphalt pavement)

The calculation yielded:

$$n = \frac{30 \times 10^2}{\frac{5^2}{4}(30-1)+10^2} = \frac{3000}{281.25} = 10.67 \approx 11$$

The calculation showed n = 10.67, rounded up to 11 sample units. However, this research examined all 30 sample units to obtain comprehensive condition assessment.

2.3 Data Collection

Data collection employed two primary approaches:
Primary Data: Obtained directly from field surveys through:

- Road distress observation
- Distress measurement (length, width, depth dimensions)
- Distress documentation through photography

Secondary Data: road maps from Google Maps

2.4 Research Equipment

Equipment used in this research included:

- Survey forms for recording field observations
- Measuring tape for distress dimension measurement
- Chalk or markers for distress area marking
- Camera/smartphone for visual documentation
- Writing tools and clipboard for systematic field recording

2.5 Data Analysis Using IKP Method

The IKP method based on Pd 01-2016-B [7] was used to evaluate pavement conditions. Analysis steps included:

1. Field survey to observe road conditions
2. Measuring distress quantities and types
3. Determining distress severity levels (low, medium, high) according to IKP classification tables
4. Calculating distress area using Equation (2):

$$A = P \times L \tag{2}$$

   Where A = area, P = length, L = width

5. Calculating distress density using Equation (3) for area-type distresses and Equation (4) for linear-type distresses:

$$\text{Density} = \frac{\text{Ad}}{\text{As}} \times 100\% \tag{3}$$

$$\text{Density} = \frac{\text{Ld}}{\text{As}} \times 100\% \tag{4}$$

   Where:
   Ad = total distress area for each severity level (m²)
   Ld = total distress length for each severity level (m)
   As = total segment area (m²)

6. Determining Deduct Values (DV) from density-severity relationship curves for each distress type
7. Calculating Total Deduct Value (TDV)
8. Determining Corrected Deduct Value (CDV) using TDV-CDV relationship curves
9. Calculating IKP value for each segment using Equation (5):

$$\text{IKP} = 100 - \text{CDV} \tag{5}$$

10. Calculating overall IKP value using Equation (6):

$$\text{IKP} = \frac{\sum \text{IKP}_{(s)}}{N} \tag{6}$$

   Where:
   IKP(s) = IKP value for each sample unit
   N = total number of sample units

2.6 Maintenance Recommendations

After data analysis using the IKP method, maintenance recommendations were developed based on pavement condition classifications according to the IKP guideline Pd 01-2016-B [7] as Table 1.

Table 1. Maintenance recommendations according to the IKP guideline

Condition Category	IKP Value	Maintenance Recommendation
Excellent	≥ 85	Routine Maintenance
Good	70 – 85	Periodic Maintenance
Fair	55 – 70	Structural Improvement
Poor	< 55	Reconstruction/Recycling

3. RESULTS AND DISCUSSION
3.1 Sample Unit Determination

Based on the IKP guideline Pd 01-2016-B section 7.2 point d, the first step is determining pavement units with the requirement that each unit must have an area of (225 ± 90) m², meaning each unit must have an area ranging from 135 m² to 315 m². This research used 175 m² per unit (225 – 50 = 175). Thus, each unit dimensions were obtained as follows:

- Length = 50 meters
- Width = 3.5 meters
- Area = 175 m²

Therefore, the number of units for the 1500-meter road section was 30 units. The layout of segment division is presented in Figure 1.

Figure 1. Segment Division Layout

Referring to IKP guideline sub-chapter 7.2 regarding the determination of minimum sample units requiring inspection, a minimum of 11 units was required. However, this research examined all 30 units to obtain comprehensive condition assessment. The calculation for obtaining the minimum of 11 sample units referring to the IKP guideline using Equation (1) was as follows:

Known:
N = 30 segments
e = 5 (based on assumption)
d = 10 (assumption for asphalt pavement) as stated in IKP

$$n = \frac{30 \times 10^2}{\frac{5^2}{4}(30-1) + 10^2}$$

$$n = \frac{3000}{281.25}$$

$$n = 10.67 \; n \approx 11$$

The calculation result of the minimum sample number showed n = 10.67, which was then rounded up to 11 segments. Therefore, the number of segments surveyed in this research was 11 segments to achieve 95% confidence level for IKP estimation, although all 30 segments were actually surveyed for comprehensive analysis.

3.2 Pavement Distress Types Identified

Field survey results identified various pavement distress types on the Pakuhaji Road section, including alligator cracking, longitudinal and transverse cracking, potholes, patching, raveling, lane/shoulder drop-off, depression, and reflection cracking. These distresses occurred with varying severity levels distributed across multiple road segments (Table 2).

Table 2. Summary of Distress Types Found on Pakuhaji Road Section

Distress Type	Severity Levels Found	Most Affected Segments
Alligator Cracking	Low, Medium, High	Mauk: 8, 16, 22, 23, 25, 28; Sepatan: 1, 7, 22, 24
Longitudinal/Transverse Cracking	Low, Medium, High	Mauk: 4, 14, 24, 29; Sepatan: 4, 15, 23, 30
Potholes	Low, Medium, High	Mauk: 2, 4, 11, 15, 17, 22, 25; Sepatan: 4, 8, 11, 14, 16, 21, 25, 28
Patching	Medium	Mauk: 10
Raveling	Medium, High	Mauk: 14, 27; Sepatan: 12, 20
Lane/Shoulder Drop-off	Low, Medium, High	Mauk: 1, 3, 7, 19, 20, 21, 24, 28; Sepatan: 22, 30
Depression	Low, Medium, High	Mauk: 1, 5, 7, 8, 12, 16, 20, 23; Sepatan: 5, 13, 17, 22
Reflection Cracking	Low, Medium, High	Mauk: 1, 3, 6, 9, 10, 13, 17, 19, 23, 26, 27; Sepatan: 6, 17, 18, 20

3.3 Distress Density Calculation

Distress density was calculated for each distress type in every segment based on the measured dimensions. Higher density values indicate more extensive distress coverage within the segment area. The Table 3 shows density calculation example for Segment 1 (Sepatan direction).

Table 3. Example of Distress Density Calculation (Segment 1, Sepatan Direction)

Distress Type	Severity	Total Area (m²)	Density (%)
Alligator Cracking	High	0.75	0.2
Alligator Cracking	Medium	0.59	0.2

3.4 Deduct Value Determination

Deduct Values (DV) were obtained from density-severity relationship curves for each distress type as provided in the IKP guideline [7]. Higher DV values indicate more severe impact on pavement condition. Table 4 shows DV determination example for selected segments.

Table 4. Example of Deduct Value Determination

Segment	Direction	Distress Type	Severity	Density (%)	Deduct Value
1	Sepatan	Alligator Cracking	High	0.2	18
1	Sepatan	Alligator Cracking	Medium	0.2	10
2	Mauk	Potholes	High	0.1	58

3.5 Corrected Deduct Value Calculation

Corrected Deduct Values (CDV) were calculated by considering multiple distress types occurring simultaneously in each segment. The CDV represents the combined effect of all distresses on pavement condition (Table 5). The maximum CDV for each segment was determined through iterative reduction of deduct values according to the IKP procedure [7].

Table 5. Example of CDV Calculation (Segment 1, Sepatan Direction)

Iteration	DVs > 2	q	Total DV	CDV
1	18, 10	2	28	20
2	10, 2	1	12	16

Maximum CDV = 20

3.6 Indeks Kondisi Perkerasan (IKP) Values

IKP values were calculated using the formula IKP = 100 - CDV. The following table 5 and table 6 present IKP values for all segments in both directions (Table 6 and 7)

Table 6. IKP Values for Mauk Direction Segments

Segment	IKP Value	Condition Category	Segment	IKP Value	Condition Category
1	84	Good	16	68	Fair
2	42	Poor	17	40	Poor
3	96	Excellent	18	92	Excellent
4	58	Fair	19	96	Excellent
5	82	Good	20	64	Fair
6	92	Excellent	21	88	Excellent
7	92	Excellent	22	38	Failed
8	66	Fair	23	74	Good
9	76	Good	24	60	Fair
10	96	Excellent	25	52	Poor
11	40	Poor	26	72	Good
12	90	Excellent	27	90	Excellent
13	61	Fair	28	68	Fair
14	64	Fair	29	100	Excellent
15	42	Poor	30	100	Excellent

Average IKP (Mauk) | 73 | Good

Table 7. IKP Values for Sepatan Direction Segments

Segment	IKP Value	Condition Category	Segment	IKP Value	Condition Category
1	80	Good	16	38	Failed
2	84	Good	17	95	Excellent
3	86	Excellent	18	97	Excellent
4	88	Excellent	19	96	Excellent
5	86	Excellent	20	98	Excellent
6	98	Excellent	21	92	Excellent
7	68	Fair	22	82	Good
8	66	Fair	23	92	Excellent
9	84	Good	24	82	Good
10	92	Excellent	25	84	Good
11	78	Good	26	78	Good
12	64	Fair	27	88	Excellent
13	82	Good	28	64	Fair
14	82	Good	29	92	Excellent
15	90	Excellent	30	87	Excellent

Average IKP (Sepatan) | 83 | Good
Overall Average IKP | 78 | Good

3.7 Discussion

The analysis results reveal significant variation in pavement conditions along the Pakuhaji Road section. The Mauk direction shows an average IKP of 73 (good category), while the Sepatan direction shows an average IKP of 83 (good category), with an overall average of 78 (good category). However, individual segments display conditions ranging from excellent (IKP 100) to failed (IKP 38), indicating non-uniform pavement deterioration patterns.

The findings of this study are consistent with research conducted on the Prancis Dadap Highway in Tangerang Regency by Afdal et al. [8], which used the Surface Distress Index (SDI) method to evaluate pavement conditions. Their study found average SDI values of 51.17 in the airport direction and 67.83 in the Dadap direction, both classified as moderate damage. Similar to the current study, they identified potholes as the dominant distress type, with percentages of 31.8% in the airport direction and 30.9% in the Dadap direction. The presence of heavy vehicles, particularly large trucks and containers serving warehousing facilities in the area, was identified as a primary factor accelerating pavement deterioration [8]. This parallels the conditions observed on the Pakuhaji Road, where freight transport vehicles contribute significantly to pavement distress.

The importance of systematic pavement condition assessment and consistent maintenance is further emphasized by research on pavement deterioration modeling using Markov chain processes [9]. That study, conducted on 34 national road segments in West Java Province totaling 1,789.76 km, demonstrated that probabilistic Markov chain methods can accurately model changes in pavement condition. The results showed that consistent, routine handling of road deterioration maintained stable conditions (good and moderate categories) at 95.72% over a ten-year analysis period, while unstable conditions (light and heavy damage) continued to decrease to 4.28% [9]. This finding strongly supports the maintenance approach recommended in the current study, highlighting that routinely and consistently addressing road deterioration yields favorable pavement condition values and assists in optimal maintenance policy development.

Dominant Distress Types: Alligator cracking was the most prevalent distress, particularly in segments with high traffic loads. This distress type indicates structural fatigue failure due to repeated traffic loading, suggesting that the pavement structure may be inadequate for current traffic volumes. According to the IKP guideline [7], alligator cracking with high severity requires reconstruction or structural overlay. Potholes were also widespread, especially in segments with pre-existing cracking where water infiltration accelerated deterioration through weakening of the base course. High severity potholes require full-depth patching or reconstruction. These findings align with Afdal et al. [8], who noted that potholes frequently appear on road sections with obstructed water flow or poor drainage systems, conditions that can exacerbate damage particularly in areas with high rainfall or geographical factors affecting surface water flow.

Directional Differences: The Sepatan direction generally exhibited better pavement conditions compared to the Mauk direction. This difference may be attributed to variations in traffic composition, with potentially higher heavy vehicle volumes in the Mauk direction causing accelerated deterioration. Segments 16 (Sepatan) and 22 (Mauk) showed the lowest IKP values (38 each), falling into the failed category requiring immediate reconstruction according to the IKP guideline criteria (IKP < 55). Similar directional disparities were observed by Afdal et al. [8], where the Dadap direction showed more severe damage forms despite having five segments with no visible deterioration, resulting in a higher average SDI value (67.83) compared to the airport direction (51.17).

Comparison with Previous Studies: The IKP values obtained in this study are consistent with findings from similar research on Indonesian roads using the IKP method. Kusmaryono et al. [10] reported IKP values ranging from poor to excellent on the Bogor Road in Depok City, with alligator cracking and longitudinal cracking as dominant distress types. Rafidin and Susilo [11] found an average IKP of 82.1 (good category) on the Krebet-Hayam Wuruk Road in Malang Regency, recommending periodic maintenance similar to this study's recommendations for segments with good conditions. Baharudin and Susilo [12] reported that the Slamet-Kedungrejo Road section in Malang Regency showed varying conditions with dominant alligator cracking (36%) and edge cracking (7%), recommending periodic maintenance. The Markov chain modeling study by Isradi et al. [9] provides valuable insight into the long-term implications of maintenance decisions. Their simulation of road handling programs over ten years demonstrated that consistent annual maintenance actions across all road sections can maintain stable conditions at 95.72%, while delaying handling actions—whether routine, periodic, or rehabilitation—results in poor pavement condition values and significantly higher handling costs [13],[14]. This underscores the importance of implementing the maintenance recommendations derived from the current IKP analysis without delay.

Maintenance Implications : The variation in IKP values across segments necessitates differentiated maintenance approaches according to the IKP guideline classifications [7]:

- Segments with excellent to good conditions (IKP ≥ 70) require only routine or periodic maintenance to preserve current conditions. For example, Segments 29 and 30 in both directions with IKP 100 (excellent) require routine maintenance such as crack sealing and surface cleaning.
- Segments with fair conditions (IKP 55-70) need structural improvement to prevent further deterioration. For instance, Segment 8 in both directions with IKP 66 (fair) requires structural improvement through overlay or partial reconstruction.

- Segments with poor to failed conditions (IKP < 55) require reconstruction or recycling to restore adequate serviceability. Segment 16 in Sepatan direction and Segment 22 in Mauk direction with IKP 38 (failed) require immediate reconstruction or recycling.

These recommendations align with the maintenance approach validated by the Markov chain modeling study [9], which demonstrated that appropriate and timely maintenance interventions based on condition assessment can optimize pavement performance and extend service life. As noted by Afdal et al. [8], without adequate maintenance, pavement deterioration worsens with high traffic intensity and heavy commercial vehicle loads, ultimately impacting user comfort and safety. Therefore, implementing the recommended maintenance programs based on IKP values is essential for sustainable road infrastructure management in Tangerang Regency.

4. CONCLUSIONS

Based on the research and analysis of pavement conditions on the Pakuhaji Road section in Tangerang Regency from STA 0+000 to STA 3+000 using the Indeks Kondisi Perkerasan (IKP) method, in accordance with the Ministry of Public Works and Housing Circular Letter No. 19/SE/M/2016 (Pd 01-2016-B), the following conclusions can be drawn. First, the types of pavement distress identified on the Pakuhaji Road section include alligator cracking, longitudinal and transverse cracking, potholes, patching, raveling, lane/shoulder drop-off, depression, and reflection cracking. These distresses occur at varying levels of severity and are distributed across multiple road segments, with alligator cracking and potholes being the most dominant types.

Second, based on IKP calculations according to Pd 01-2016-B, the Mauk direction has an average IKP value of 73 (good condition), while the Sepatan direction has an average IKP value of 83 (good condition), resulting in an overall average IKP value of 78 (good condition). These relatively similar values indicate that both directions require similar maintenance approaches, specifically periodic maintenance in accordance with the IKP classification guidelines.

Third, the IKP evaluation results indicate that pavement deterioration requires different maintenance approaches for each segment based on the obtained IKP values. Segments with high IKP values, such as Segments 29 and 30 (IKP 100, excellent condition), require routine maintenance. Segments with moderate IKP values, such as Segments 8 and 28 (IKP 66–68, fair condition), require structural improvement. Meanwhile, segments with low IKP values, such as Segment 16 in the Sepatan direction and Segment 22 in the Mauk direction (IKP 38, failed condition), require reconstruction with more intensive treatment.

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